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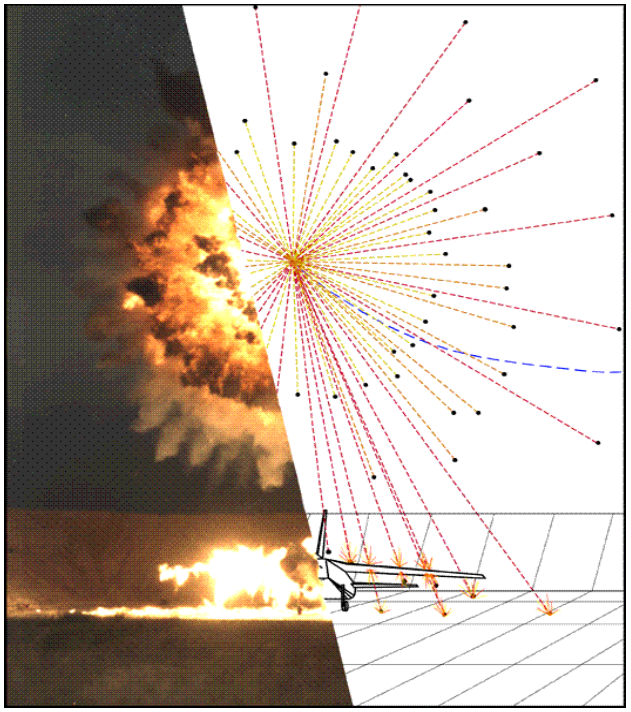
Validating M&S with T&E Data: Pitfalls, Problems and Possible Solutions



And one example…

NDIA T&E Conference
3 Mar 2010

David H. Hall
SURVICE Engineering Company
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Outline

- **Background**
- **Pitfalls & Problems**
- **Potential Solutions**
- **An Example**

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Background

- **M&S in T&E: Cost Savings or Cost Burden?**
  - M&S use touted as “saving money in T&E”
  - But often it seems to just cost more money
- **Validation often the sticking point**
  - How to demonstrate that M&S are “good enough”?
  - Validation data often are either not collected, not adequate, or not accurate
- **OUSD funded SMART Project developed cost-effective VV&A approach**
  - Including modelers’ involvement in planning T&E events to support M&S validation
  - “Generic M&S Validation Test Plans”

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Perceived Pitfalls & Problems

- **Validation is “too hard”**
  - Takes too long, costs too much, no useful product
- **Don’t know when to stop**
  - What’s “good enough?
- **Statistics often don’t tell you much**
  - What does a “statistically significant difference” really mean?
- **Can’t get enough validation data to cover domain of interest**
  - Can’t run enough tests, can’t get the data you need
- **Validation not recognized as a process**
  - It’s not a one-time event
- **Can’t get good range data**
  - Instrumentation not designed for M&S validation requirements

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Potential Solutions

- **Validation is "too hard"**
  - **Don't focus on the wrong things**
  - **Design validation program around intended uses of M&S**
    - » **Focus on parameters and outputs of greatest impact and interest**
  - **Include BOTH functional and end-to-end validation events**
    - » **End-to-end validation focuses on outputs of greatest interest**
    - » **Functional validation focuses on parameters of greatest impact**
    - » **Sensitivity Analyses support both**
- **Don't know when to stop**
  - **What's "good enough?**
- **Statistics often don't tell you much**
  - **Statistical significance vs. "analytical significance"**
- **Can't get enough validation data to cover domain of interest**
  - **Costs too much, takes too long, can't get the data you need**
- **Validation not recognized as a process**
  - **It's not a one-time event**
- **Can't get good range data**
  - **Instrumentation not designed for M&S validation requirements**

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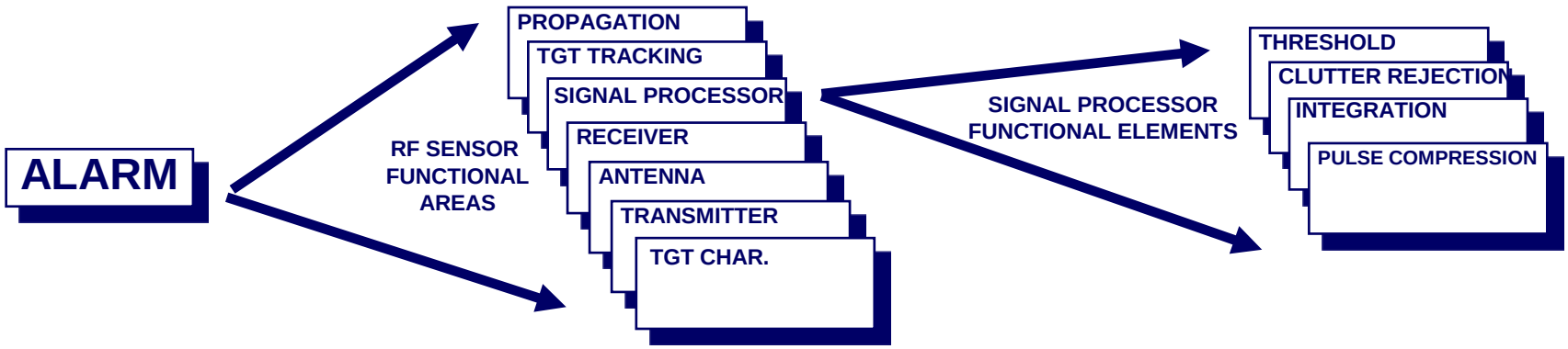
Example Functional Area Template



1.0 TARGET CHARACTERISTICS
- 1.1 FLIGHT PATH
- 1.2 SIGNATURE
  - 1.2.1 RCS
    - 1.2.1.1 STATIC
    - 1.2.1.2 DYNAMIC
  - 1.2.2 FLUCTUATIONS
- 1.3 ECM
  - 1.3.1 NOISE
    - 1.3.1.1 ON-BOARD
    - 1.3.1.2 OFF-BOARD
    - 1.3.1.3 STANDOFF
  - 1.3.2 DECEPTION
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2.0 PROPAGATION
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5.0 ANTENNA
- 5.1 GAIN

6.0 SIGNAL PROCESSING
- 6.1 THRESHOLD
- 6.2 CLUTTER REJECTION
  - 6.2.1 MTI
  - 6.2.2 DOPPLER FILTERS
- 6.3 INTEGRATION
- 6.4 PULSE COMPRESSION

7.0 TARGET TRACKING
- 7.1 ANGLE
- 7.2 RANGE
  - 7.3 DOPPLER
  - 7.4 ANTENNA SCAN

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Potential Solutions

- Validation is too hard
- **Don’t know when to stop**
  - **“Good enough” is only determined by how you’re planning on using M&S output**
- Statistics often don’t tell you much
  - Statistical significance vs. “analytical significance”
- Can’t get enough validation data to cover domain of interest
  - Costs too much, takes too long, can’t get the data you need
- Validation not recognized as a process
  - It’s not a one-time event
- Can’t get good range data
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How to Know when to Stop

- **Validation is the degree to which simulation outputs match the "real world"**
  - **"Good enough" is determined by how the simulation will be used**
    - » **Only way to guarantee you'll know when to quit doing validation is to focus on what you need from the model**
  - **Sensitivity Analyses are extremely helpful in determining what's good enough**
- **Validation always comes down to a comparison between simulation predictions and some representation of the "real world"**
  - **As adjudicated by experts in the application, the subject matter area, and the test data**

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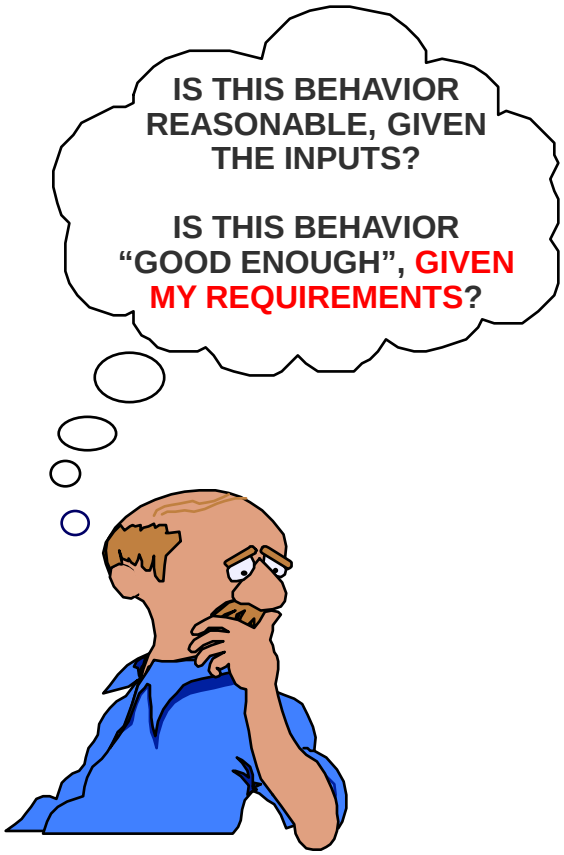
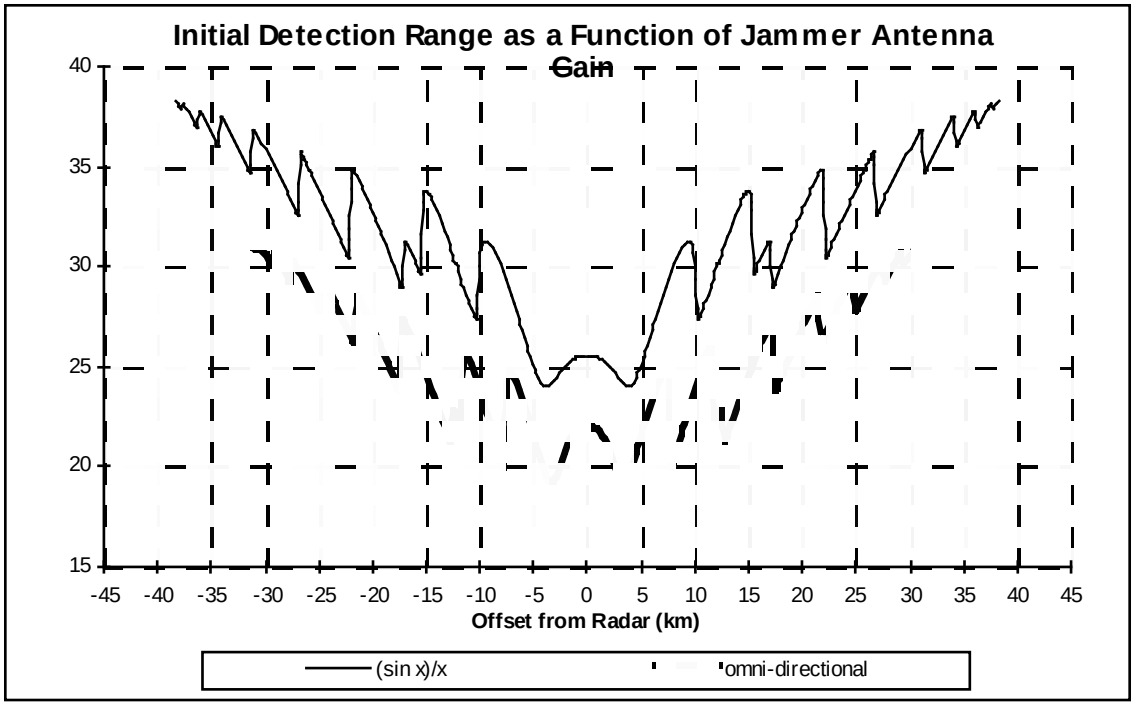
Is this Good Enough?





Antenna Pattern	Mean (m)	s (m)	Normalized Mean Difference	% Change
Omni-directional (baseline)	25.26	3.38	-	-
(sin X)/X	30.67	4.00	0.05	9.67

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Potential Solutions

- Validation is too hard
- Don’t know when to stop
- **Statistics often don’t tell you much**
  - **Just because two sets of data show a statistical difference may not mean the difference is significant to your application**
  - **Ask not whether a difference is statistically significant, but ask rather whether it’s “analytically significant”**
- Can’t get enough validation data to cover domain of interest
  - Costs too much, takes too long, can’t get the data you need
- Validation not recognized as a process
  - It’s not a one-time event
- Can’t get good range data
  - Instrumentation not designed for M&S validation requirements

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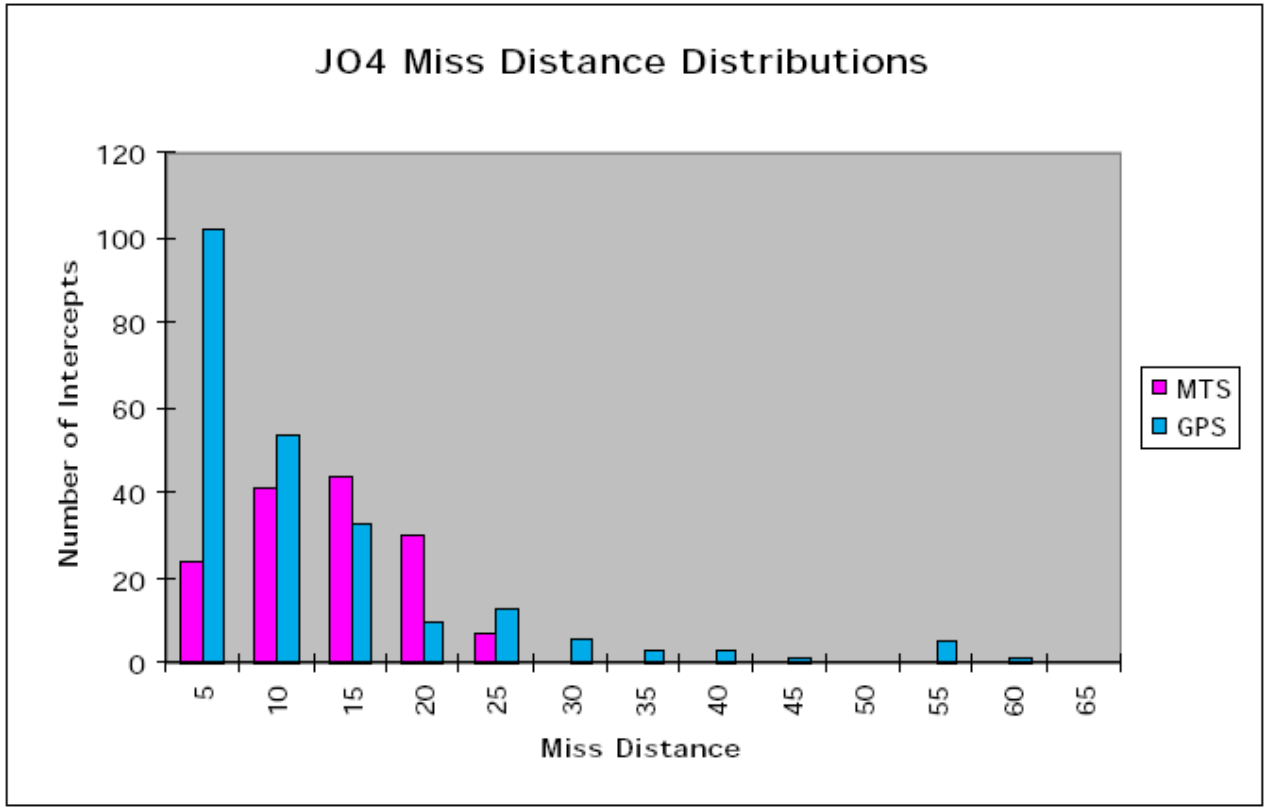
Two Measured Miss Distributions for the Same Missile System



Distributions

"MTS" = Rayleigh
"GPS" = Poisson

MTS Pk = (0.72 – 0.76)
GPS Pk = (0.74 - 0.80)

Output of Interest

Are these significantly different?

They are statistically different distributions, but what about analytically?

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Potential Solutions

- Validation is too hard
- Don't know when to stop
- Statistics often don't tell you much
- **Can't get enough validation data to cover domain of interest**
  - **Concentrate on intended uses to focus validation data collection**
    - » **What are key questions to be answered with M&S outputs?**
    - » **What parameters drive those outputs?**
    - » **Sensitivity analyses**
  - **Share costs across programs**
  - **Recognize benefits and limitations of all three validation processes:**
    - » **Benchmarking**
    - » **Face validation**
    - » **Results validation**
- Validation not recognized as a process
  - It's not a one-time event
- Can't get good range data
  - Instrumentation not designed for M&S validation requirements

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Three Validation Techniques

- **Benchmarking: Comparison of M&S outputs with outputs of another M&S that is accepted as a "standard"**
  - **Benefit of easy and cost-effective comparison matrix**
  - **Limited by acceptability of benchmark simulation**

- **Face Validation: Comparison of M&S design and outputs (under well-defined conditions) with the expectations and opinions of SME in the area of interest**
  - **Benefit of wide expertise in the subject matter area, community acceptance**
  - **Limited by choices of SME, data for them to evaluate**

- **Results Validation: Comparison of M&S outputs with the results of test measurements made under identical conditions as M&S inputs**
  - **Benefit of actual real-world test results**
  - **Limited by instrumentation assets, range assets, cost, schedule, etc.**

In combination, these three can help to cover the waterfront of interest

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Potential Solutions

- Validation is too hard
- Don’t know when to stop
- Statistics often don’t tell you much
- Can’t get enough validation data to cover domain of interest
- **Validation not recognized as a process**
  - **Validation is a gradual process of “shining light” on the capabilities of the model**
  - **Validation is never done, just done enough…**
  - **Accreditation is the “one-time event”**
- Can’t get good range data
  - Instrumentation not designed for M&S validation requirements

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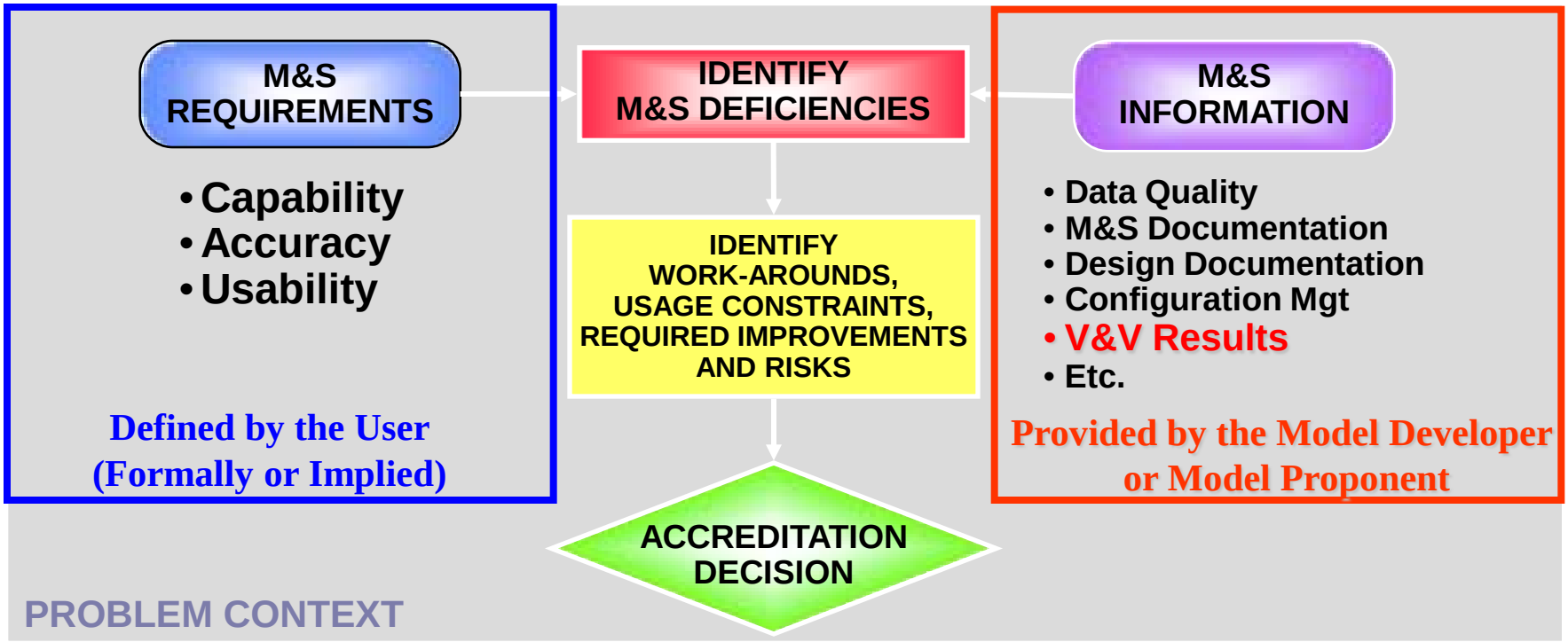
The Essence of Accreditation



TO PROVE THE M&S IS SUITABLE FOR THE NEED

REQUIRES AN OBJECTIVE COMPARISON
OF M&S REQUIREMENTS WITH M&S INFORMATION
WITHIN THE CONTEXT OF THE PROBLEM

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Potential Solutions

- Validation is too hard
- Don’t know when to stop
- Statistics often don’t tell you much
- Can’t get enough validation data to cover domain of interest
- Validation not recognized as a process
- **Can’t get good range data**
  - **Involve modelers up front**
  - **Sensitivity analyses drive data requirements**
  - **Notional Test plans/standardized test plans & reports**
  - **Calibrate test articles (especially threat systems)**

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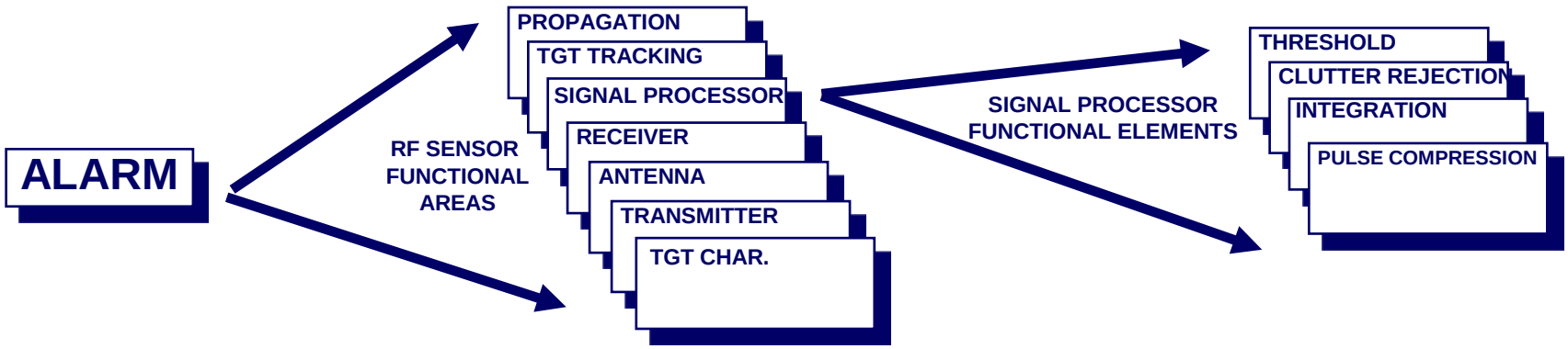
Notional Test Plans for Each Function AND End-to-End Model



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Developed by modelers to identify potential test procedures for validation

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Notional On-Board ECM Test Plan

1. Discussion
2. Notional Test Procedure
    1. ECM Conditions (VGPO, RGPO, Inverse Gain, etc.)
    2. Radar Conditions (track-while-scan, conscan, monopulse, etc.)
    3. Target Conditions (RCS, flight path, etc.)
3. Data/Accuracy Requirements (Data to be recorded)
    1. Calibration Requirements
    2. Jammer Signal Level & waveform (time, modulation, frequency, phase)
    3. Target Signal Level
    4. True target position and attitude
    5. Perceived target position and attitude
    6. AGC time-varying voltage
    7. Track error detector time-varying voltage
4. Data Processing Requirements

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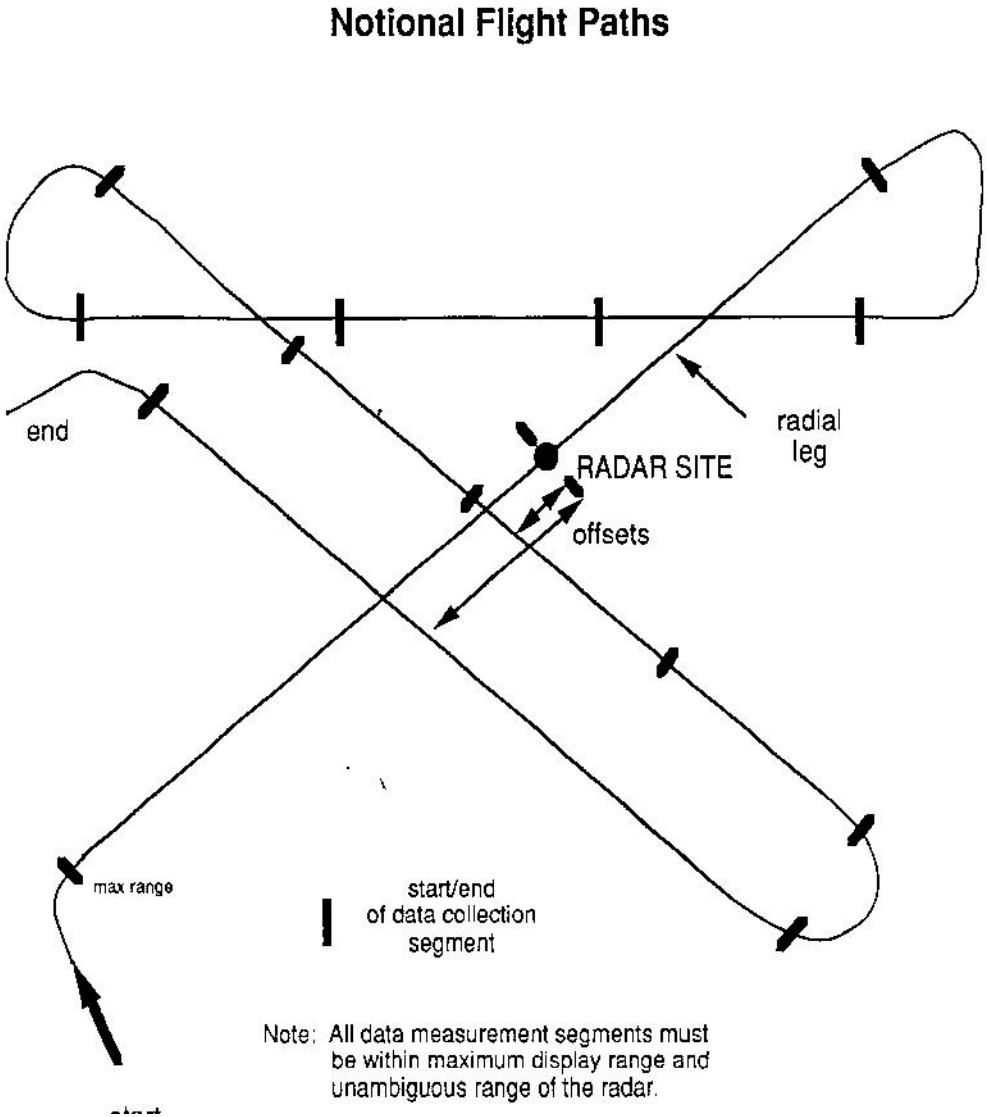
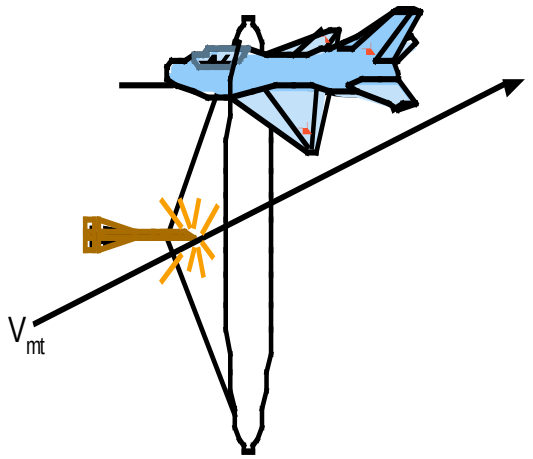
Radar Model Notional Test Plan



Example: Validating Missile Proximity Fuze Models

- **Sensitivity Analyses help determine validation data accuracy requirements**
  - **And identify drivers based on model intended use**
- **"Model-Test-Model" approach helps set up test conditions**
  - **And evaluate test results**



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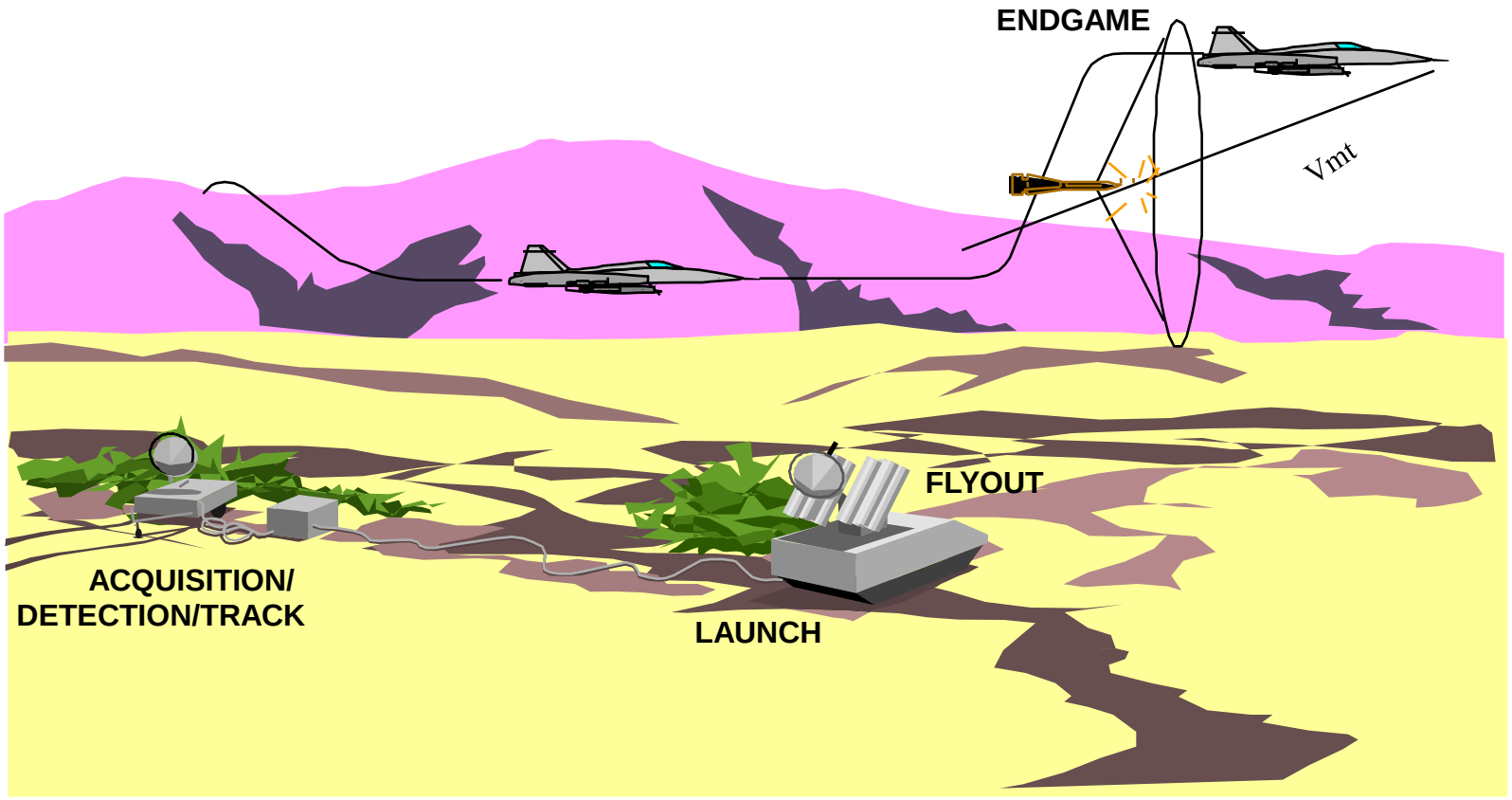
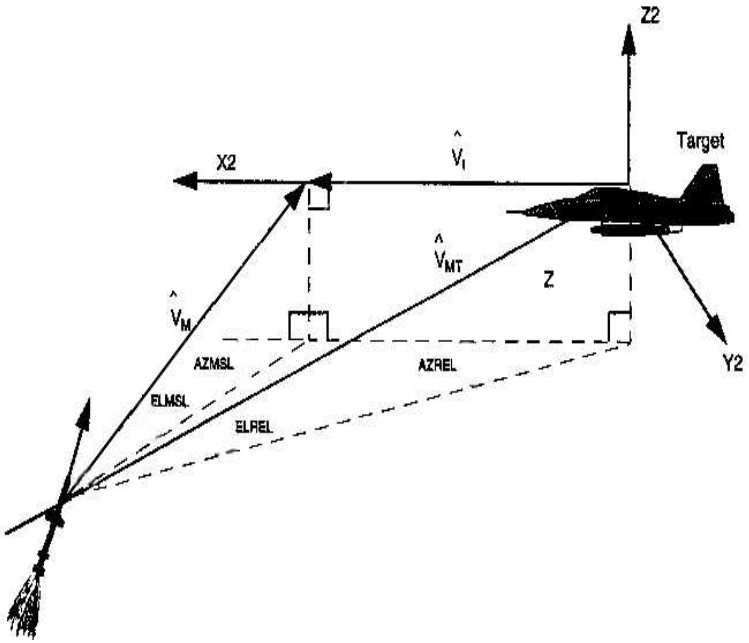
Typical Surface-to-Air Missile Engagement



Endgame Parameters Affecting Pk

- **Primary parameters**
  - Intercept geometry parameters
    - » Miss distance, direction
    - » Vm, Vt
    - » Approach angles
    - » Angles of attack
  - Fuze declaration position [on Vmt]
  - Target Vulnerability
- **Secondary parameters**
  - Fuze parameters: detection thresholds, etc.
  - Warhead parameters: ejection angle, etc.
  - Fault trees: redundancies, etc.



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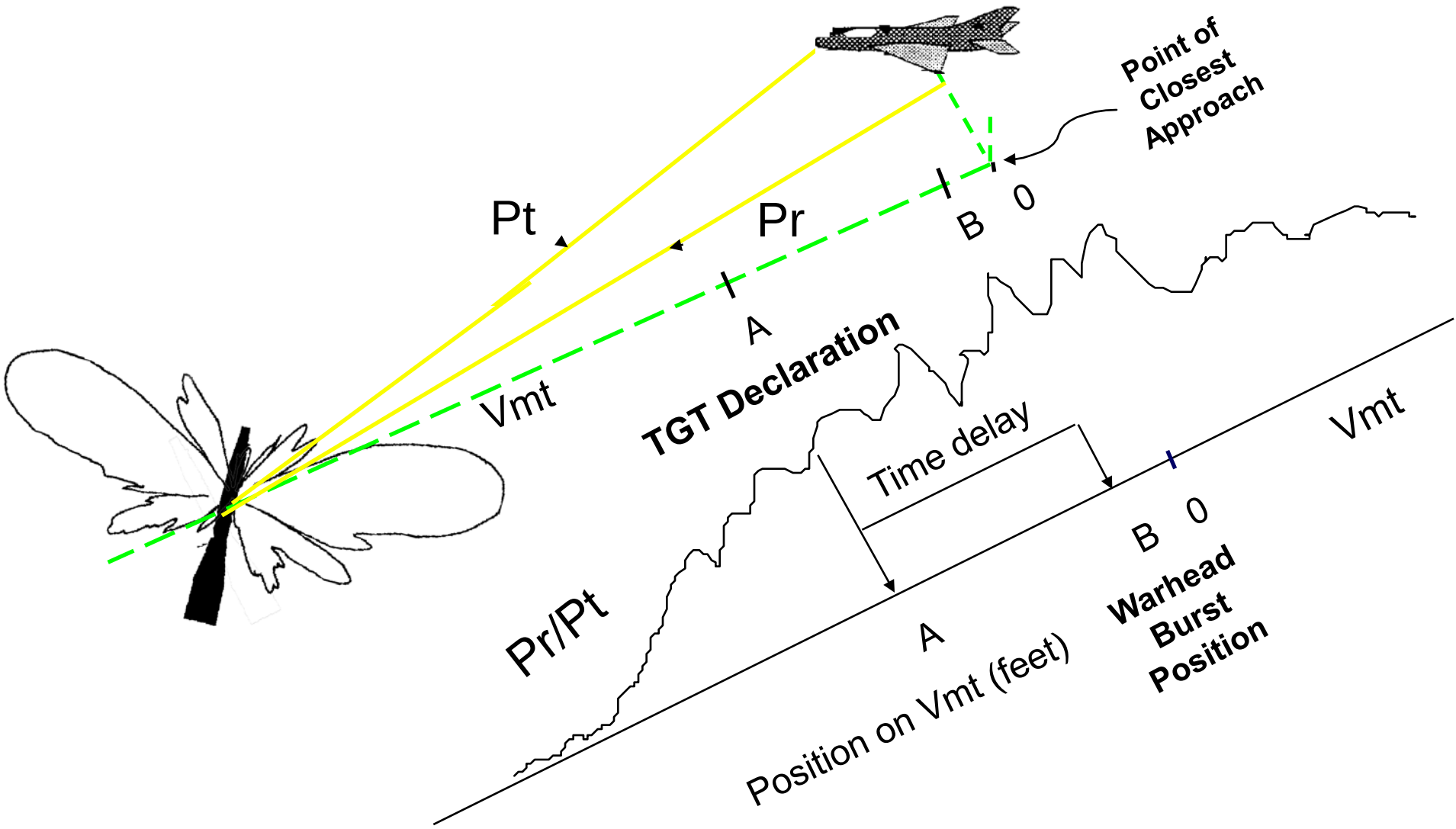
Fuze Determines Burst Point



How Good Does the Fuze Model Need to Be? What Drives Pk the Most?

- **Sensitivity Analysis Can Support the answers:**
  - **Determine Effect on Pk Caused by Errors in Inputs to the Endgame**
  - **Compare results to Pk accuracy requirements for specific applications**
  - **Example: Net Reduction in Lethality (NRL) for ECM**

$$NRL = 1 - \frac{Pk(wet)}{Pk(dry)}$$

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Sensitivity Analysis Results

Primary Drivers of Pk (in order):

1. **Fuzing (Burst Position)**
2. **Miss Distance**
3. **Az**
4. **El**
5. **Yaw**
6. **Pitch**

Relative importance depends on specific intercept conditions, type of missile and type of target

It Is Impossible to Know the Validity of Simulated Pk Without Knowing the Validity of the Fuze Model

- **Errors in fuzing prediction can change the predicted Pk from zero to one or vice versa**

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P(K) Sensitivity to Fuze Detection Position

- Missile size target
- Narrow beam, active fuze
- Small warhead

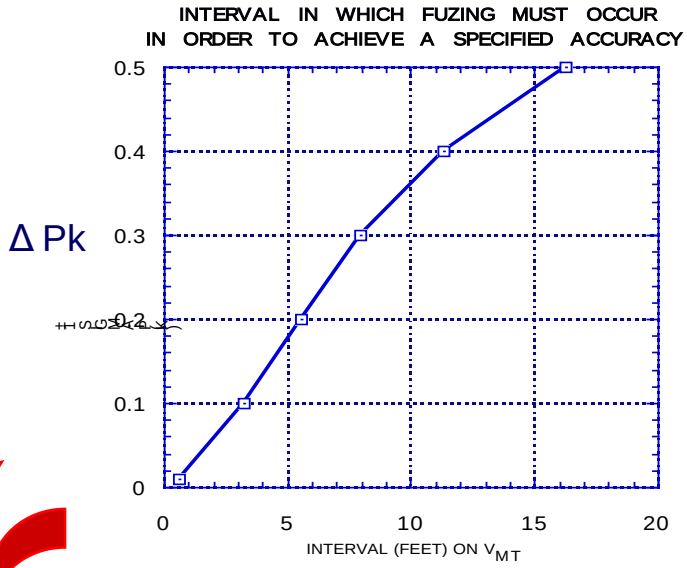

Figure I-3. Interval in Which Fuzing Must Occur To Achieve A specified P(K) Accuracy

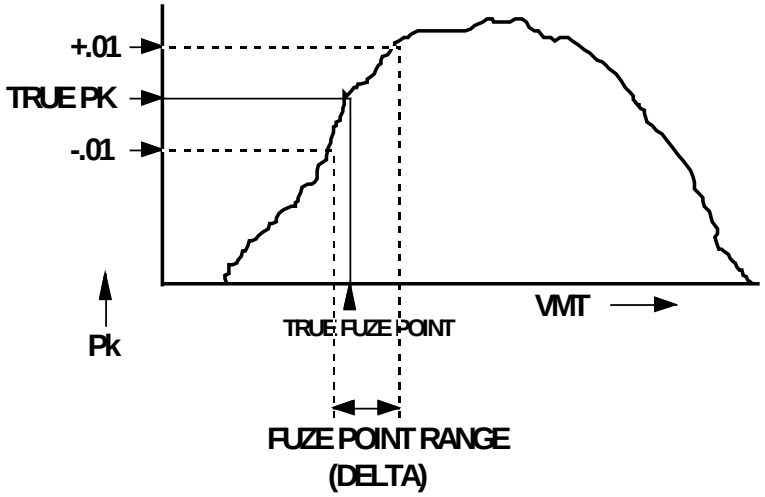

Figure I-2. P(K) Profile Along Vmt

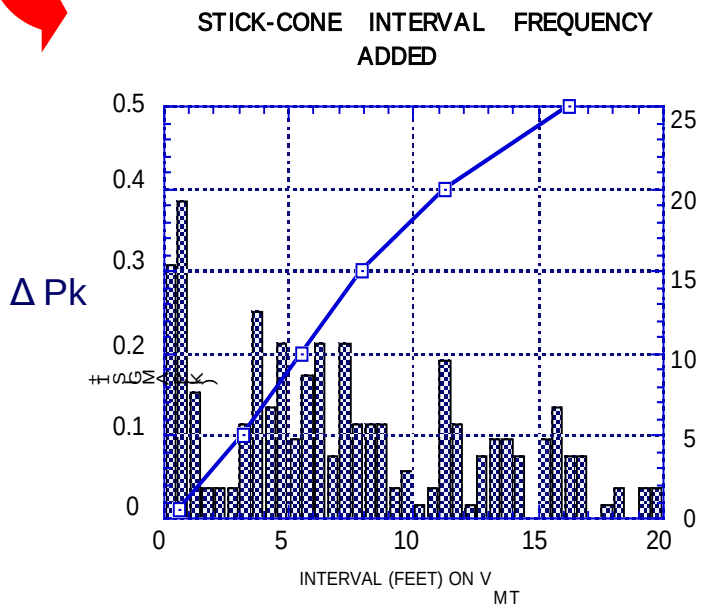

Figure I-3A. Interval in Which Fuzing Must Occur (on Vmt) To Achieve a Specified P(K/F) Accuracy

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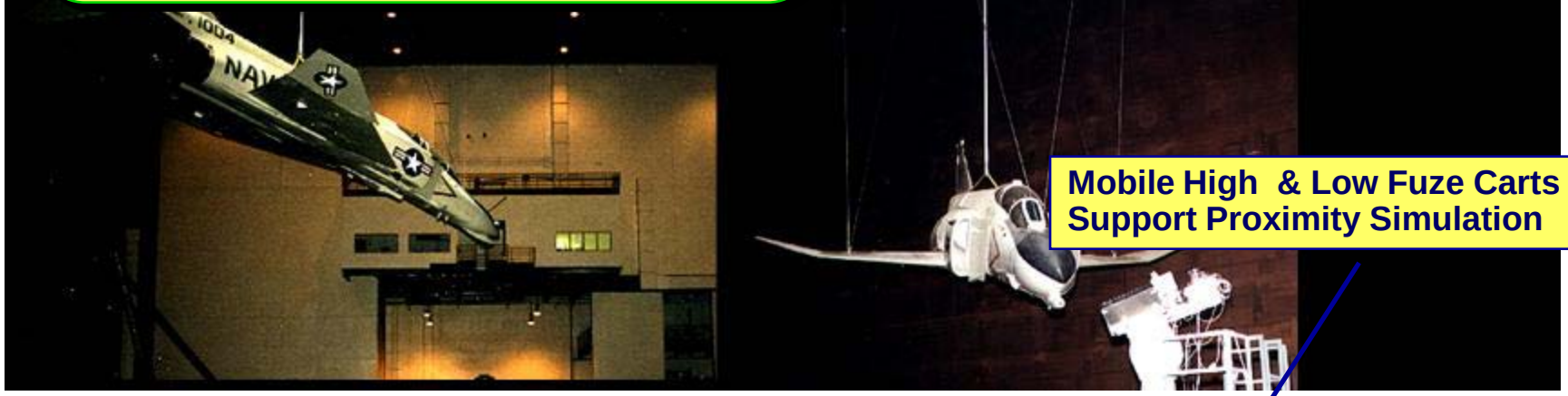
Missile Engagement Simulation Arena (MESA)

- Unique Facility for Evaluation of Missile Proximity Fuzes Against Full Scale Targets
- Effects of Near Field Signatures (Aircraft or Missile) on Threat Missile Fuze Performance

- Realistic Encounter Simulations Provide:
  - **Fuze Performance (Pd)**
  - **Warhead Burst Point**
  - **Countermeasures Effects**
  - **Overall Missile Performance**
  - **Effectiveness Analysis Support**
  - **M&S Validation Data**
  - **Linked with Missile SIMLAB**



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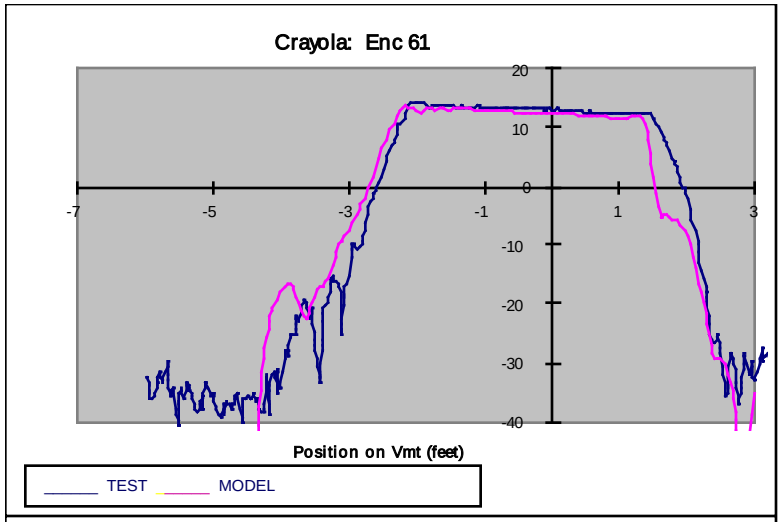
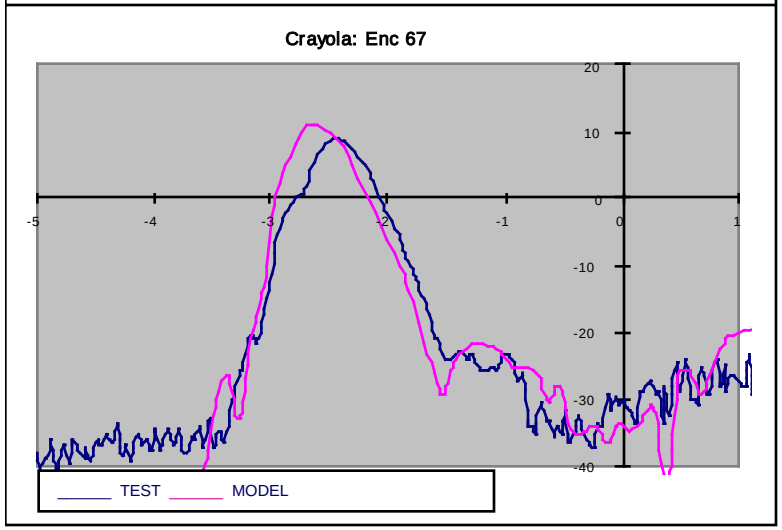
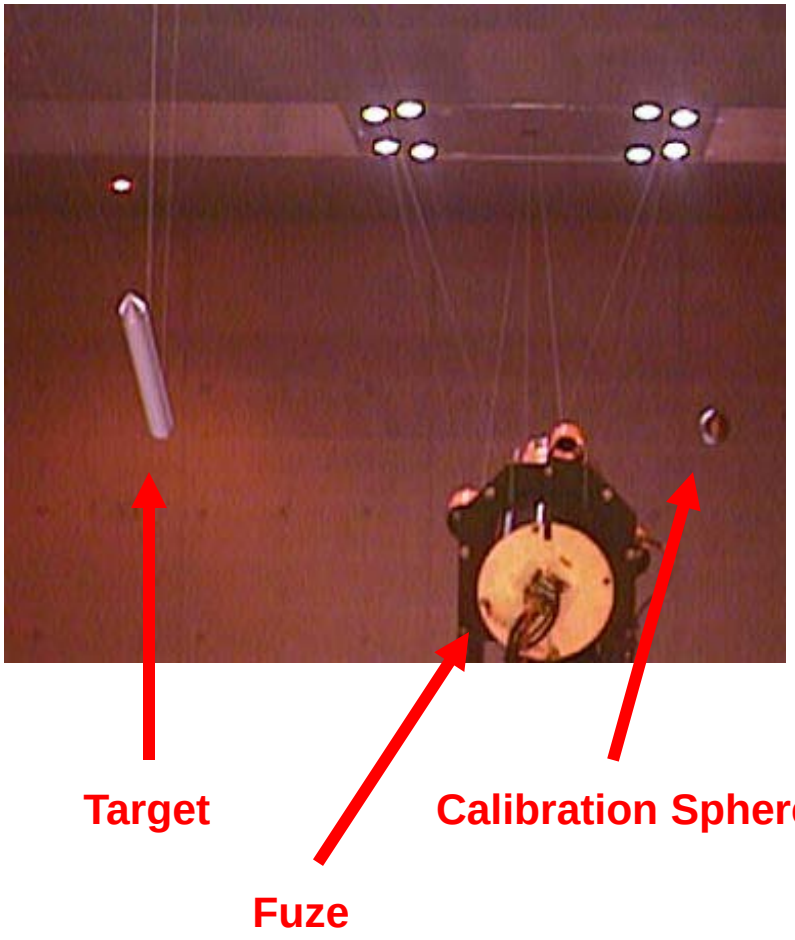
Example MESA Measurements vs. GTD* Model "Crayola" Target







*Geometrical Theory of Diffraction

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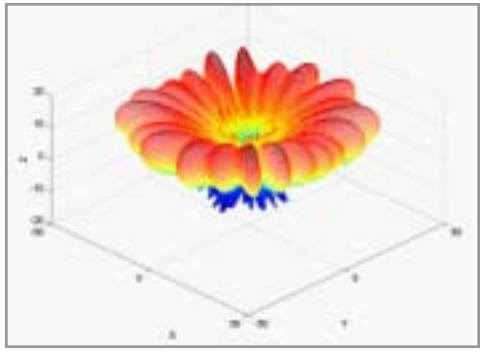
Fuze Model Validation

Baseline Fuze Logic Model

Intel or System Developer

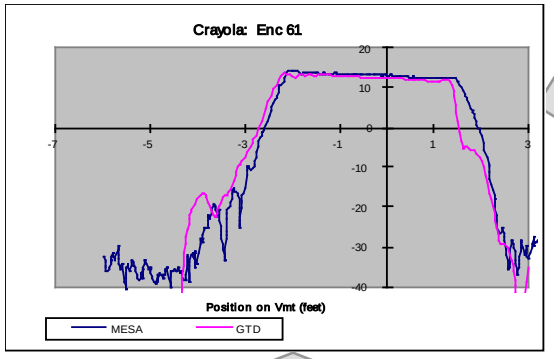
Add

Antenna Pattern Measurements

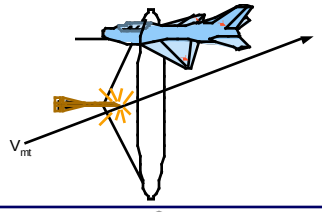


and

Test Data Collection

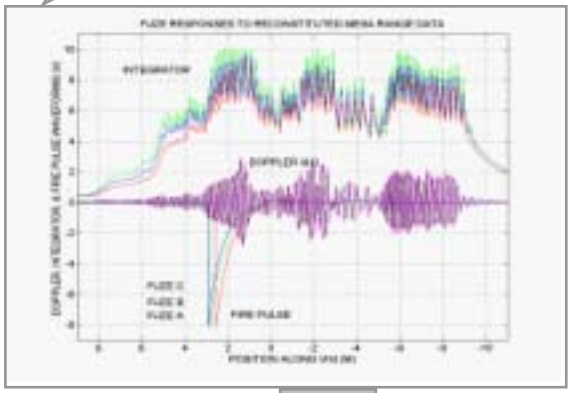


Sensitivity Analyses



Near-Field Target Signature Model
(Simple and/or Complex)

Model/Data Comparison



SME Review of comparison and Pk Sensitivity Analyses determines "When to Stop"

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Summary

- **Validation can be hard, but doesn't have to be "too hard"**
  - Design M&S validation program around intended uses
- **Figure out when to stop before you start**
  - Use sensitivity analyses to help determine accuracy requirements
- **Use statistical techniques where they make sense**
  - Often the best use is to evaluate adequacy of collected test data
- **Cover the domain of interest**
  - Use SME review of sensitivity analyses, available test data and benchmarking against accepted M&S to expand scope of range data collection
- **Recognize that validation is really a never-ending process**
  - Just stop when you can get off the validation ride with a supportable accreditation decision
- **Maximize the quality of your range data**
  - Design test data collection plan around M&S validation requirements

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